Potassium deficiency in soils and crops

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Emerging Soil Fertility Constraint in Dryland Agriculture

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PREFACE

Agriculture is the back bone of Indian economy with about two thirds of the population residing in rural areas directly or associated it for their livelihood and contributing to 19% of the Gross Domestic Product. The relative slow increase in agricultural production in recent years as compared to the quantum jump witnessed during the period of green revolution has become a mater of concern for the entire nation. Intensification of agriculture has caused serious strain on the soil system. The soils are showing fatigue ness and factor productivity is declining. The two important factors come in our way of further intensification are soil fertility and environmental safety. With the initiation of green revolution in late seventies, India has made remarkable progress in food security, poverty reduction and per capita income. Even though India has made considerable progress over the years in increasing the food grain production to a recent 217 mt in 2008-09, the performance over the last ten years has been unsatisfactory. The growth rate in agriculture has not kept pace with the phenomenal growth rate in industrial and services sectors. Obviously a concerted effort is required to improve the condition of Indian Agriculture, which involves policy intervention, frontier research, public-private partnership, and involvement of farmers at different stages starting from technology generation to its adoption.

Soil fertility and its evaluation is one area which needs immediate attention since it is now established that an arrest in the productivity of several crops is due to ever decreasing soil fertility on one hand and an imbalanced application of plant nutrients on the other. The deficiency of several major and minor plant nutrients such as K, S, Ca, Zn. Fe and B are emerging in time and space. Among the essential plant nutrients, potassium assumes greater significance since it is required in relatively larger quantities by plants and besides increasing the yield, it immensely improves the quality of the crop produce. Most the literature in the past indicated the sufficiency of K in Indian soils, but continuous intensive production systems with K supply resulted in depletion of soil K reserves. Potassium nutrition has special significance in dryland agriculture as it regulates water relations under moisture stress environment. This document covers K status in rainfed regions of India, role of K in drought tolerance, K additions, K removals under intensive systems, K deficiency in different crop plants, nutrient recommendations, on farm impacts of K application on field crops, vegetables and fruit crops. Information regarding potassium deficiency symptoms and impacts are useful to farmers to identify K deficiency in the field and so for the extension specialists, line departments, policy makers and soil fertility researchers.

Ch.Srinivasa Rao
B.Venkateswarlu
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Anil Kumar Singh

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1. Introduction

Soil is an exhaustible storehouse of plant nutrients. Soil fertility and its evaluation is an area which needs immediate attention since it is now established fact that an arrest in the productivity of several crops is due to ever decreasing soil fertility on the one hand and imbalanced application of plant nutrients on the other. The food production increased during past five decades and with time the number of elements deficient in Indian soils and crops also increased. Among the essential plant nutrients, potassium assumes greater significance since it is required in relatively larger quantities by plants and besides increasing the yield, it immensely improves the quality of the crop produce and improves N and P use efficiency.

2. Role of K in plants

- Activates more than 60 enzymes and directly or indirectly involved in all major plant growth processes
- Promotes photosynthesis, resulting in formation of carbohydrates, oils, fats and proteins
- Involved in movement of photosynthates to storage organs (seeds, tubers, roots, fruits)
- Improves efficiency of N fertilizers by enhancing production of proteins
- Essential for formation of sugars in plants (sugarcane, potato and other tuber crops)
- Increases ability of plants to withstand stresses - drought, frost, pest, disease, lodging, poor drainage etc.
- Regulates absorption of water by plant roots, helps development of healthy root system
- Regulates respiration in plants
- Improves quality of crops and prolongs shelf life of crop produce
- Essential for efficient biological N fixation

3. Role of Potassium in Water Stress Management in

Dryland Agriculture

The major limiting factor for crop yield in arid and semi-arid regions is the amount of soil moisture available to plants during the growing season. Soil moisture influences K^+ uptake by plants by affecting root growth and the rate of K^+ diffusion in the soil towards the root. At the lower side of the optimal soil moisture content, increasing soil moisture increases the effective diffusion coefficient of K^+ and therefore increases K^+ uptake. Increasing the moisture content above the optimum resulted in slow root growth due to oxygen shortage. The reduction in root elongation was reflected in lower K^+ uptake. The rate of root elongation is a crucial parameter in the uptake of nutrients that are strongly adsorbed to the soil and their concentration in the soil solution is usually very low. Combined effects of low temperatures and low moisture can be alleviated by increasing the concentration of K^+ in the soil.

The function of stomata is to control water loss from the plant via transpiration. When K^+ is deficient, the stomata cannot function properly and water losses from plant may reach damaging levels. This has been demonstrated in field experiment in barley in which plants were exposed to hot wind. This caused an immediate increase in transpiration rate, more severe in K^+ deficient plants which took long time to react by closing stomata, while the K^+ supplied plants respond quickly in closing stomata and preserved internal moisture. The stomat a closes in response to water stress, thereby reduction in carboxylation efficiency of the chloroplasts. Stomatal closure for long time leads to photo reduction of O_2 to toxic O_2 species. This effect of drought can be more severe when plants are grown with inadequate supply of K^+, as K^+ itself is required for stomatal movement. The larger K^+ requirement of water stressed plants can be related to the protective role of K^+ against stress induced photo-oxidative damage. The protective role of K^+ in plants suffering from drought stress has been well documented.

4. Soil K Fertility in Rainfed Regions

In rainfed agro ecosystems (Fig. 1), the soils were characterized by low to high in available K status. Surface soils of Agra, S.K.Nagar, Bangalore, Hoshiarpur and Rakh Dhiansar were low in K, Faizabad, Phulbani, Ranchi, Anantapur, Akola, Hisar and Arjia were medium and at Rajkot, Indore, Rewa, Kovilpatti, Bellary, Bijapur and Solapur were high (Fig. 2). Potassium deficiency is noticed in coarse textured alluvial soils, red and lateritic and shallow soils and soils which supports continuous high yields without K addition. Vertisols and Vertic intergrades showed relatively high available K as compared to Inceptisols and Alfisols because of higher clay content and smectitic clay (Fig. 3 and 4). Potassium status of different rainfed agroecological sub-regions of India, indicated that available K of rainfed regions varied from low to high depending upon soil type, parent material, texture, mineralogy and management practices. Profile mean of available K varied from 138.8 to 195.1 kg ha^{-1} under rice based production system, from 129.2 to 188.8 kg ha^{-1} under groundnut system, 322.3 to 407.5 kg ha^{-1} under soybean system, from 76.7 to 272.3 kg ha^{-1} under cotton system, from 365.4 to 500.4 kg ha^{-1} under *rabi* sorghum system, from 85.1 to 163.1 kg ha^{-1} under pearlmillet system, 53.0 kg ha^{-1} under fingermillet and from 55.6 to 109.4 kg ha^{-1} under maize based

Fig. 1. Soil sampling sites
All India Coordinated Research Project for Dryland Agriculture in India

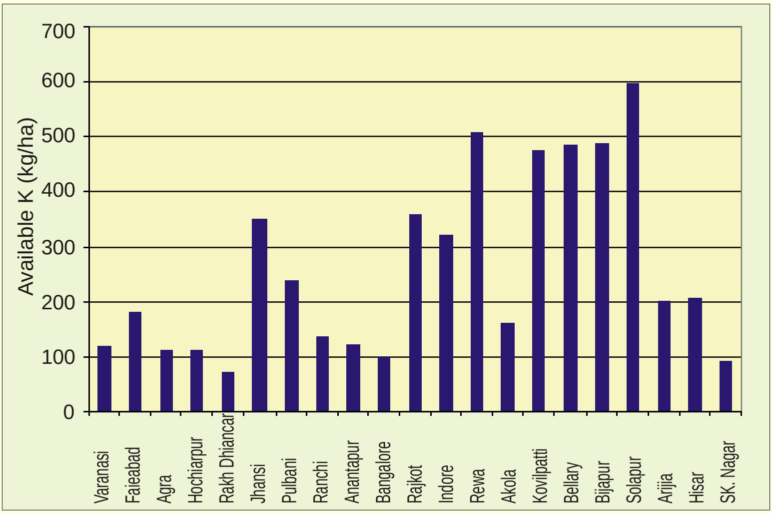


Fig. 2. Available K status in different soil types under rainfed production systems of India

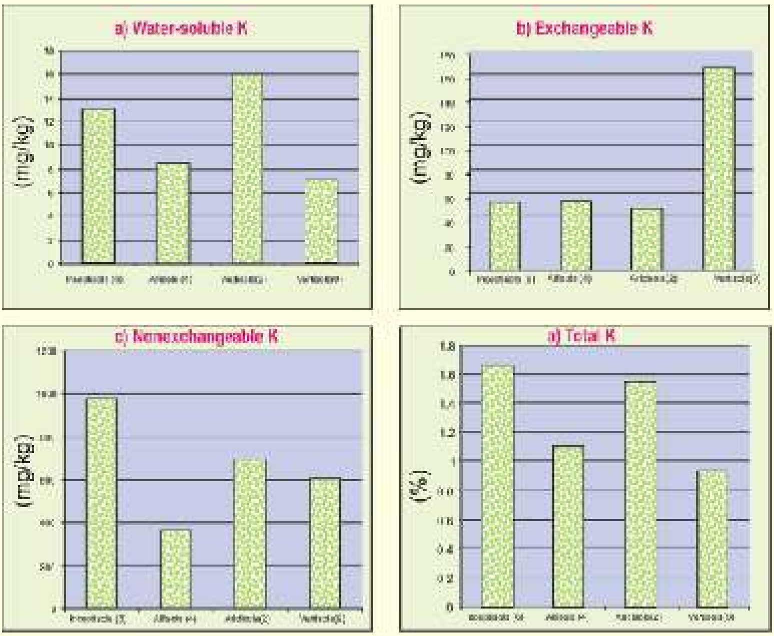
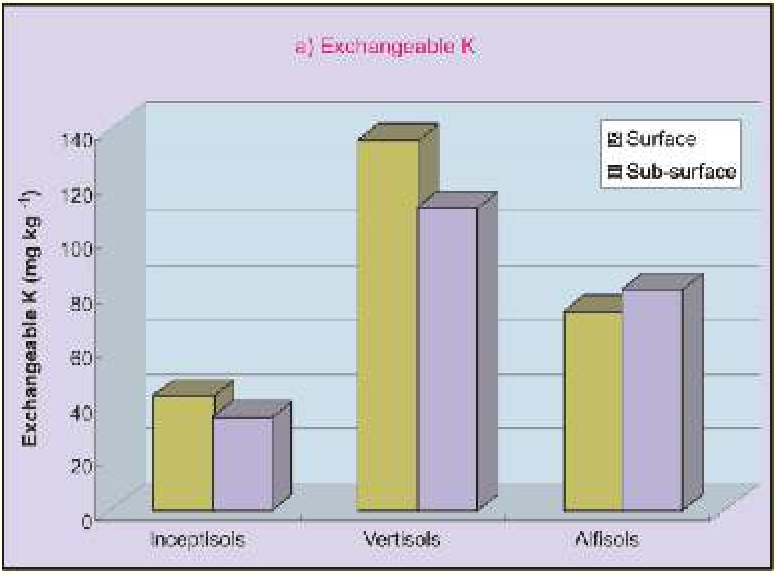


Fig. 3. K Fractions in soil types in rainfed regions of India



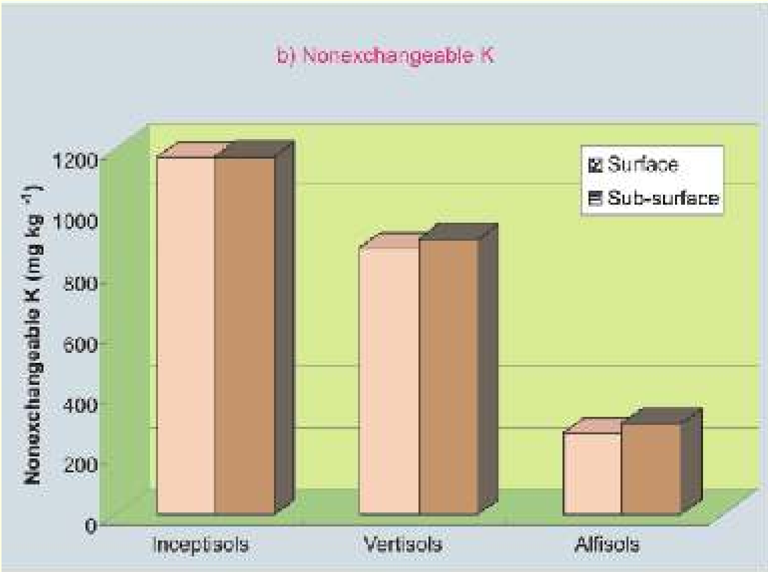


Fig. 4. K Status in dryland soils of India

Table 1. Emerging nutrient deficiencies in dryland soils (0-15 cm) under diverse rainfed production systems of India

Location	Limiting Nutrient (Low/Deficient)
Varanasi	N, Zn, B
Faizabad	N
Phulbani	N, Ca, Mg, Zn, B
Ranchi	Mg, B
Rajkot	N, P, S, Zn, Fe, B
Anantapur	N, K, Mg, Zn, B
Indore	-
Rewa	N, Zn
Akola	N, P, S, Zn, B
Kovilpatti	N, P
Bellari	N, P, Zn, Fe
Bijapur	N, Zn, Fe
Jhansi	N
Solapur	N, P, Zn
Agra	N, K, Mg, Zn, B
Hisar	N, Mg, B
SK. Nagar	N, K, S, Ca, Mg, Zn, B
Bangalore	N, K, Ca, Mg, Zn, B
Arjia	N, Mg, Zn, B
Ballowal-Saunkri	N, K, S, Mg, Zn
Rakh-Dhiansar	N, K, Ca, Mg, Zn, B

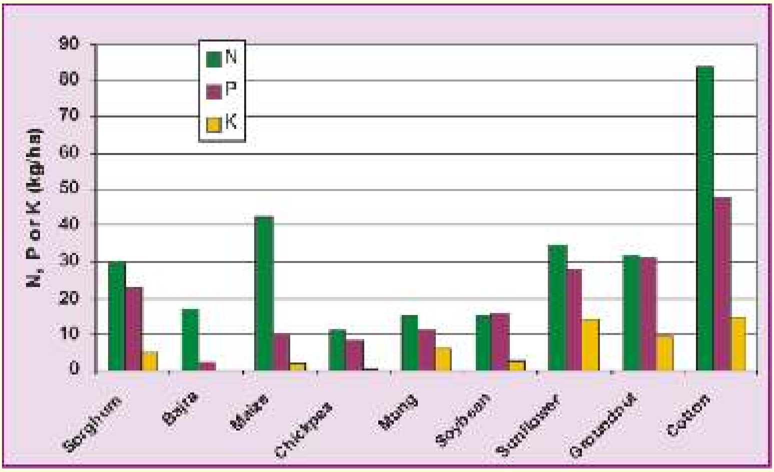
5. Fertilizer Consumption in Rainfed Agriculture

The role of fertilizers in augmenting food production in India was realized only with the introduction of high yielding dwarf varieties of wheat and other cereals. During 1966-98, the Green Revolution era, fertilizer consumption increased from 0.34 m.t. in 1961-62 to 25.15 t ha^{-1} in 2008-09 with NPK ratio of 4.5:2.0:1.0. However, there are wide disparities in fertilizer consumption between irrigated and rainfed agriculture, primarily due to uncertainty associated with rainfed crops. In India, about 80% fertilizer is consumed in the irrigated areas, and the remaining 20% is used in areas that consist 70% of the cropped area. Average NPK fertilizer consumption increased to about 120 kg ha^{-1} in irrigated conditions while the same is about 55 kg ha^{-1} under rainfed agriculture. Even among rainfed conditions major share of nutrients goes to cotton, sunflower and other commercial crops. However, fertilizers use efficiency in rainfed crops in rather low.

Nitrogen is a major limiting nutrient in dryland soils and therefore, its regular application in optimum doses is crucial in sustainable crop yields. However, its application is very low at 26 kg ha^{-1} in rainfed regions against 90 kg ha^{-1} in irrigated conditions. This is because of the variations in production levels between these regions. Again, there is lot of disparity in N consumption with in the rainfed states. However, even at existing level of N application, what is essential is to improve its use efficiency and get the maximum out of unit N application, which has economic and ecological implications. P application varied from 2 to 28 kg ha^{-1} in various rainfed rainfed crops and its crop requirement is fulfilled through P consumption except in Bajra (2 kg ha^{-1}).

Average K application in rainfed regions is 5.4 kg ha^{-1} as against 15.5 kg ha^{-1} in irrigated conditions. Its application is completely lacking in the states like Rajasthan, Gujarat, M.P, Chhattishgarh etc despite soil test status varied between low to medium. Even in other crops, application of K is low considering crop K uptake and soil K status. Consumption of NPK in predominant rainfed crops (Fig. 5) indicates cotton followed by maize and sunflower removes higher amounts of nutrients compared to other crops.

Fig. 5. Consumption of NPK in major rainfed crops in India



6. K Requirement of Different Dryland Crops

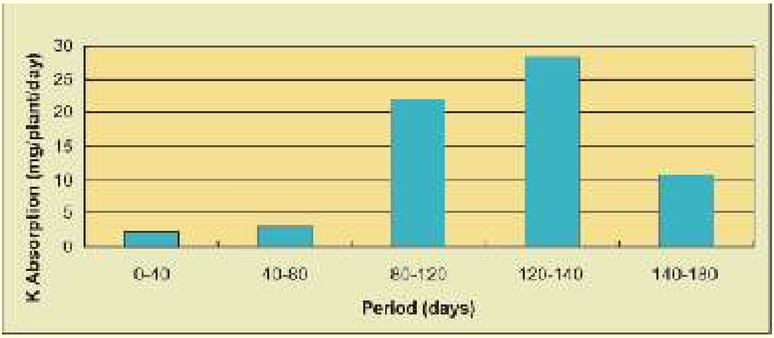
Intensive cropping invariably results in heavy withdrawal of nutrients from soils and its sustenance largely depends upon the judicious application of inputs commensurate with nutrient uptake. Nutrient uptake values generally provide a reliable estimate of nutrient requirements under varying agro-ecological regions which would form the basis for the development of a sound fertilizer recommendation strategy for realizing higher productivity and maintaining soil fertility. The average uptake of major nutrients by crops at 100 percent NPK treatments of selected intensive cropping systems indicated that in most of the cropping systems, K uptake exceeded N, especially when three crops are taken in a year like maize-wheat-cowpea(f), rice-wheat-jute fibre, maize-wheat-cowpea (f) and sorghum-sunflower hybrids. Potassium uptake in relation to N and P_2O_5 was presented in some important dryland crops in India (Table 2)

However, in the case of potassium, K release rates should be matched with daily K uptake by different crops. Some of the K loving crops like cereals, tuber crops, banana, sugarcane, tobacco, tea have higher uptake rates. For example, rate of K absorption by pigeonpea over a period of time (Fig. 5) shows maximum K absorption during 80 to 140 days. When soils are low to medium such as light textured alluvial, red and lateritic, crop needs K fertilization specially to meet the K absorption rates during these critical stages of crop growth.

Table 2. Nutrient uptake of some important rainfed crops in India

Crop	Produce	kg nutrient/tonne produce		
		N	P_2O_5	K_2O
Sorghum	Grain	22.4	13.3	34.0
Pearl millet	Grain	42.3	22.6	90.8
Rice	Grain	20.1	11.2	30.0
Chickpea	Grain	46.3	8.4	49.6
Groundnut	Seed	58.1	19.6	30.1
Soybean	Seed	66.8	17.7	44.4
Sunflower	Seed	56.8	25.9	105.0
Cotton	Seed	44.5	28.3	74.7

Fig. 6. Rate of K absorption in pigeonpea under rainfed conditions

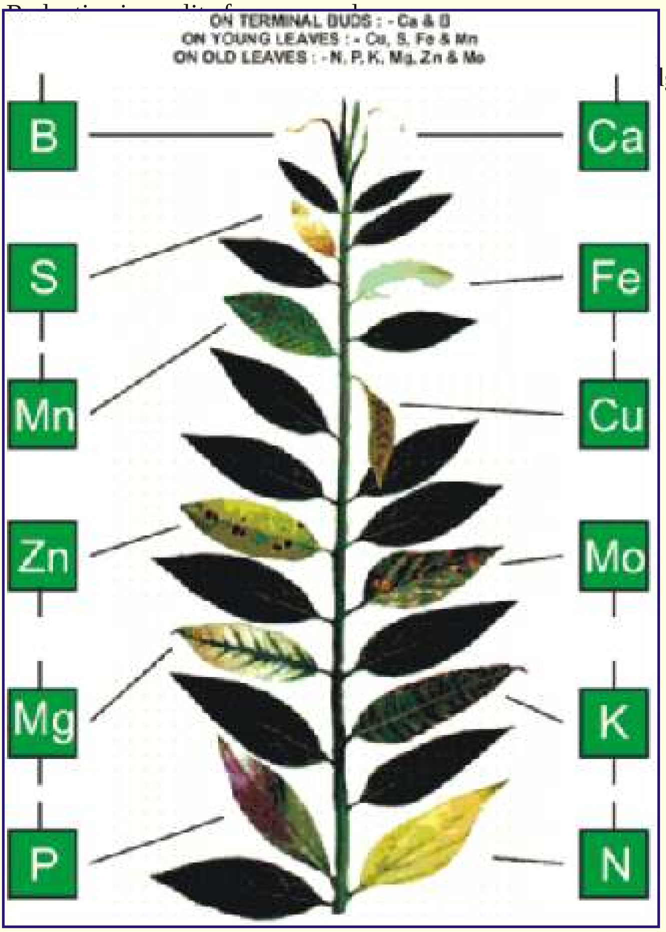


7. Potassium Deficiency in Crops

These soils are under continuous cultivation of cereals system without K application and field scale expression of K deficiency is not observed so far though grain yield responses were reported in different pulse crops. If K concentration in plant parts enters in sub-optimal levels, crop plants express K deficiencies. The very general symptoms of K deficiency in plants are: chlorosis along leaf margins followed by scorching and browning of tips of older leaves which gradually progress inwards and stunted growth. Mottles, chlorosis, necrosis (especially at tips and margins between veins). Older leaves are mostly affected. In cereals, weak stalks, roots are more susceptible to disease.

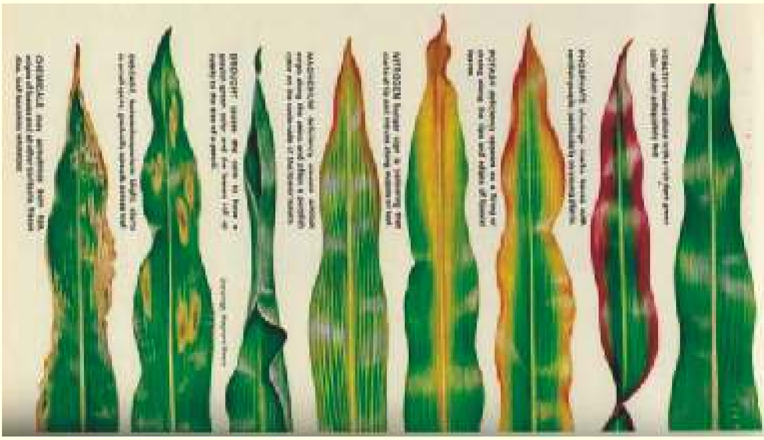
K Deficiency Symptoms

- Chlorosis along leaf margin followed by scorching and browning of the tips of older leaves which moves inwards
- Slow and stunted growth
- Weak stalks, poor root development
- Low yield, shriveled grain
- [illegible]
- lging



Typical nutrient deficiency Symptoms in crops

Guide to Nutrient Deficiency Symptoms



Typical nutrient deficiency symptoms in crop plants

Potassium deficiency in cluster bean in K deficient red soils in the farmers fields of Anantapur district

Potassium deficiency in maize (left) and soybean (right)

Potassium deficiency in soybean (close up view)

K deficiency in soybean

K deficiency in pigeonpea

K deficiency in soybean

K deficiency in groundnut

K deficiency in sorghum

Crop failure in absence of balanced nutrition in fingermillet on red soils

Good crop stand in K sufficient cotton in rainfed region (Adilabad district)

Potash fertilization in different Clusters

Need based fertilizer distribution to farmers for on farm trials
in groundnut (based on field based soil testing)

Potash in balanced nutrient application in on farm demonstrations in the villages of Andhra Pradesh

Application of Muriate of Potash in on farm trials in Nalgonda district of A.P. (Based on field based soil testing)

Potash application in groundnut and pigeonpea in farmer's fields (potash application to groundnut by line placement)

Potash application to green gram on K deficient red soils

8. Crop Response to K Additions

With a few exceptions, in all the regions there was progressive build up in crop response to 60 kg ha^{-1} K_2O (Table 3) The increasing trend in response over the years could be due to progressive intensification of agriculture with the introduction of high yielding varieties, high inputs of other nutrients especially N and P, irrigation and use of improved crop production technologies. Sorghum responded to K at Akola (Maharasthra) and Siruguppa (Karnataka) and failed to respond at Gwalior and Sehore. The data is from experiments conducted in different agroecological regions by PDCSR, Modipuram. Very high response to added K is found in regions 8, 9, 13, and 16 whereas regions 2, 5, and 14 showed a response which was relatively lower in magnitude. Average yield over the years showed positive responses to K in maize and wheat at Ludhiana and Palampur, rice at Pantnagar and *kharif* (rainy season) rice at Bhubaneswar. The yields computed over the last 3 years showed increased responses in maize at Coimbatore, soybean at Jabalpur, soybean and wheat at Ranchi and rice at Bhubaneswar. Similarly, crop response to K application after 5 to 10 years intensive cropping was obtainfed in several long term fertilizer experiments under All India Coordinated Research Project on Long Term Fertilizer Experiments

Table 3. Yield increase of rice, wheat and soybean (kg ha^{-1}) through potassium application in different agroclimatic regions during 2003-04

Agroecological region/Location	Crop	N	P_2O_5	K_2O	$N:P_2O_5:K_2O$ Ratio	Grain yield	Response (kg grain /kg K_2O)
Region 2 Kota (Light textured)	Soybean	60	120	0	1:2:0	1355	
		60	120	30	1:2:0.5	1476	4.0
		60	120	60	1:2:1	1509	2.6
	Wheat	120	120	0	6:1:0	4666	
		120	120	30	6:1:1.1	4778	3.7
		120	120	60	6:1:4	4889	3.7
Region 4 Modipuram (Alluvial)	Rice	170	30	0	6:1:0	7840	
		170	30	40	6:1:1.3	9290	36.3
		170	30	120	6:1:4	9240	11.7
	Wheat	150	30	0	5:1:0	5010	
		150	30	40	5:1:1.3	5430	10.5
		150	30	120	5:1:4	5520	4.3
Kanpur (Alluvial)	Rice	150	30	0	5:1:0	8329	
		150	30	40	5:1:1.1	8413	2.1
	Wheat	150	30	0	5:1:0	5481	
		150	30	40	5:1:1.1	5553	1.8
		150	30	120	5:1:4	640	7.7
Faizabad (Alluvial)	Rice	150	60	0	5:2:0	6784	
		150	60	40	5:2:1.3	7096	7.8
		150	60	0	5:2:0	3436	
		150	60	40	5:2:1.3	3948	12.8
		150	60	120	5:2:4	3856	3.5
Varanasi (Alluvial)	Rice	150	30	0	5:1:0	6132	
		150	30	40	5:1:1.3	6757	15.6
		150	30	120	5:1:4	6458	2.7
	Wheat	150	30	0	5:1:0	3294	
		150	30	40	5:1:1.3	3632	8.5

Agroecological region/Location	Crop	N	P_2O_5	K_2O	$N:P_2O_5:K_2O$ Ratio	Grain yield	Response (kg grain /kg K_2O)
Ludhiana (Alluvial)	Rice	150	60	0	5:2:0	8939	
		150	60	50	5:2:1.8	9367	8.6
		150	60	150	5:2:5	10125	7.9
	Wheat	150	60	0	5:2:0	5710	
		150	60	50	5:2:1.8	6050	6.8
		150	60	150	5:2:1.8	5990	1.9
Palampur (Tarai)	Rice	100	25	0	4:1:0	5833	
		100	25	40	4:1:1.6	5754	-
		100	25	125	4:1:5	6092	2.1
	Wheat	100	25	0	4:1:0	2538	
		100	25	40	4:1:1.6	2948	10.3
Region 5 Navsari (Black)	Kharif rice	150	120	0	5:4:1	4233	
		150	120	40	5:4:1.3	4167	-
		150	120	120	5:4:4	4317	0.7
	Rabi rice	150	120	0	5:4:0	5778	
		150	120	40	5:4:1.3	6222	11.1
		150	120	120	5:4:4	6556	6.5
Sirguppa	Kharif rice	150	100	0	6:4:0	4073	
		150	100	40	6:4:1.8	4288	5.4
		150	100	120	6:4:5	3956	-
	Rabi rice	150	100	0	6:4:0	-	
		150	100	40	6:4:1.8	-	
Region 8 Coimbatore (Medium black)	Kharif rice	150	120	0	5:4:0	6018	
		150	120	30	5:4:1	6320	10.1
		150	120	60	5:4:2	7169	19.2
	Rabi rice	150	120	0	5:4:0	7239	
		150	120	30	5:4:1	7729	16.3
		150	120	60	5:4:2	7560	5.4

Agroecological region/Location	Crop	N	P_2O_5	K_2O	$N:P_2O_5:K_2O$ Ratio	Grain yield	Response (kg grain /kg K_2O)
Thanjavur (Black)	Kharif rice	150	30	0	5:1:0	8396	
		150	30	100	5:1:3.3	9438	10.4
	Rabi rice	150	30	0	5:1:0	6303	
		150	30	100	5:1:3.3	6618	3.2
		150	30	150	5:1:5	6660	2.4
Maruteru (black)	Kharif rice	150	120	0	5:4:0	3793	
		150	120	40	5:4:1.3	4553	19.0
		150	120	120	5:4:4	4048	2.1
	Rabi rice	150	120	0	5:4:0	6811	11.8
		150	120	40	5:4:1.3	7283	
		150	120	120	5:4:4	7045	
		150	30	120	5:1:4	3802	
Pantnagar (Mollisol)	Rice	170	30	0	6.3:1:0	7100	
		170	30	40	6.3:1:1.3	7400	7.5
	Wheat	170	30	0	6.3:1:0	5281	
		170	30	40	6.3:1:1.3	6218	23.4
Region 12 Ranchi (Red)	Rice	150	60	0	5:2:0	489	
		150	60	50	5:2:1.8	5750	17.2
		150	60	150	5:2:5	6694	12.0
	Wheat	150	60	0	5:2:0	3350	
		150	60	50	5:2:1.8	3430	1.6
		150	60	150	5:2:5	4135	
Region 13 Bhubaneswar (Lateritic)	Kharif rice	150	100	0	6:4:0	5306	
		150	100	40	6:4:1.8	6250	23.6
		150	100	120	6:4:5	5202	-
	Rabi rice	150	100	0	6:4:0	-	
		150	100	40	6:4:1.6	-	
		150	100	120	6:4:5	-	
		100	25	125	4:1:5	2583	

Agroecological region/Location	Crop	N	P_2O_5	K_2O	$N:P_2O_5:K_2O$ Ratio	Grain yield	Response (kg grain /kg K_2O)
Region 14 Jammu (Alluvial)	Rice	150 150	100 100	0 40	6:4:0 6:4:1.6	9502 9559	1.4
	Wheat	150 150 150 170	100 100 100 30	0 40 120 120	6:4:0 6:4:1.6 6:4:5 6:1:4	6172 6776 7227 5156	15.1
Region 16 Sabour (Black)	Rice	150 150	30 30	0 50	5:1:0 5:1:1.8	6826 7672	16.9
	Wheat	150 150 150	30 30 30	0 50 100	5:1:0 5:1:1.8 5:1:3.3	4470 5132 5343	13.2

Source: PDCSR Annual Report, 2005

9. On Farm Demonstrations

Farmer participatory soil samples were collected from about 60 villages in 8 districts of Andhra Pradesh (Fig. 6). About twelve hundred farmer's fields were tested for their soil fertility status. Twenty per cent of farm holds were covered considering farm size, topography and production system. Details of the villages under the project are presented in Table 4. Number of house holds varied from 216 (B.Yerragudi) to 734 (Zamistapur). In the semi-arid tropics, the deficiency was noticed in coarse textured soils, some red soils and in soils in which had high crop yield levels without K applications for long period of time. In the present study also, 54% of 83 farmers' fields were K deficient in B.Yerragudi, where soils were sandy undulating and highly degraded. In other clusters also where soils are red and sandy, K deficiency was found in the order of 14% (Dupahad), 17% (Ibrahimpur) and 18% (Zamistapur). Continuous cultivation of cotton, sorghum, maize and groundnut crops on these soils resulted in further K deficiency. Black soils (Vertisols and Vertic intergrades) were found to be sufficient in available K because of higher clay content and nature of clay. Potassium status of different agro ecological sub-regions of India indicated that available K of rainfed regions varied from low to high, depending upon soil type, parent material, texture, mineralogy and management practices. In another set of samples collected from farmers fields in Kadapa cluster indicated the 100 % K deficiency. Similarly K deficiency in soils of Nalgonda district is predominant.

Fig. 6. Map of Andhra Pradesh indicating eight target districts where clusters are located

Table 4. Details of cluster, soil type and dominant crops in the village

District	Cluster	No of villages	Soil Type	Crops
Adilabad	Seethagondi	8	Black	Cotton + Pigeonpea
Nalgonda	Dupahad	9	Red and black	Castor + Pigeonpea, vegetables
Khammam	T.Cheruvu	7	Red and black	Cotton, sorghum
Mahbubnagar	Zamistapur	3	Red and black	Castor, sorghum, Groundnut
Anantapur	Pampanur	3	Red (gravelly)	Groundnut'
Kadapa	B Yerragudi	8	Red and black	Groundnut, Sunflower
Warangal	Jaffergudem	7	Red and black	Cotton, rice
Rangareddy	Ibrahimpur	4	Red sandy	Maize + Pigeonpea

On farm demonstrations in several hundreds of farmer's fields indicated the crop response to balanced nutrition was up to 120 per cent depending up on soil test and crop requirements. K deficiency was noticed in soils of Kadapa (groundnut, cereals and mango), Anantapur (groundnut and cluster bean), Adilabad and Mahaboobnagar districts (cotton), Rangareddy (maize), and Warangal and Khammam(Cotton). Crop response to nutrient application is much more when they were applied in balanced ratio. Most of the light textured red and lateritic soils, crop response to K was significant. Benefits of balanced nutrition were much more in vegetable crops like tomato etc.

Impacts of balanced nutrition in Nalgonda and Adilabad districts of AP.

Good groundnut crop with balanced nutrition including potassium on red soils of Anantapur

Good groundnut crop with balanced nutrition in farmers' fields in Anantapur

Sunflower with balanced nutrition (Kadapa district)

Healthy pearmillet crop with balanced nutrition in light textured red soils

Response of rice (in some cases upland rice), wheat and soybean to K application was studied in different agroclimatic regions of India. In most of the cases inclusion of K along with N and P showed considerable yield advantages. For example at Modipuram (alluvial), rice responded at 170kg N, 30 kg P_2O_5 and 40kg K_2O (6:1:1.3) showing response of 36.3 kg grain per kg K_2O. Similarly 4 q ha^{-1} additional wheat yield was obtained with 150kg N, 30 kg P_2O_5 and 40 kg K_2O (5:1:1.3) over 150 kg N and 30 kg P_2O_5 (5:1:0), showing response at 10.5 kg grain per kg of K_2O. Similar levels of responses were obtained in rice and wheat in alluvial soil belt of Faizabad, Varanasi and Ludhiana (Agroecological region 4). In case of black soils (Region 5), *rabi* rice responded at 11.1 kg grain per kg K_2O (Navsari). In black soil belt of Coimbatore and Thanjavur, rice responded to the extent of 19.2 kg grain per kg K_2O ($N:P_2O_5:K_2O$=5:2:1). Such high responses to K application were also obtained in black soil belt of Andhra Pradesh. In red and lateritic soil belt (Region 12 and 13) at Ranchi and Bhubaneswar, rice response was at 17.2 and 23.6 kg grain with kg K_2O at 5:2:1.8 and 6:4:1.8 ratio, respectively.

Performance of cotton with balanced nutrition over farmer's practice in tribal villages of Adilabad district of A.P.

Impact of balanced nutrition on cotton + pigeonpea and sorghum in Adilabad and Nalgonda districts of Andhra Pradesh

Good nursery with optimum plant nutrition

Village nutrient bank and nutrient application in Adilabad and Nalgonda districts of Andhra Pradesh

Impact of balanced nutrition on vegetable crops (tomato, capsicum and brinjal) in Kolar district of Karnataka

Impacts of balanced nutrition on mango and groundnut at Kadapa and sweet sorghum at Daulathabad (Medak district)

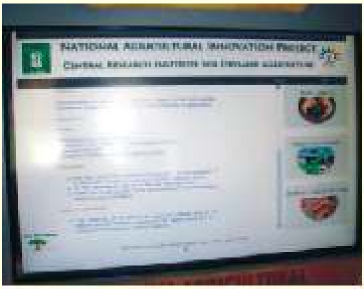
Impact of balanced nutrition on cotton and castor in Mahaboobnagar district of A.P.

10. Extension Activities

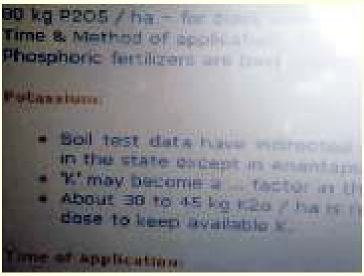
Awareness building activities for balanced nutrition in Anantapur, Adilabad and Warangal districts

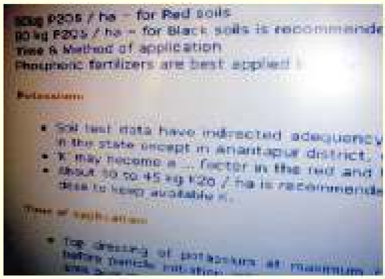
Farmers being helped to identify K deficiency using ICT interface in tribal villages of Nalgonda district

ing on Balanced Nutrition in Farmers day in Udaipur district of Rajast



Potassium recommendations for various crops in 60 villages in
8 districts of Andhra Pradesh through ICT-Kiosk





Potassium recommendations for various crops in 60 villages in 8
districts of Andhra Pradesh through ICT-Kiosk

Information centre with email facility and touch screen information
on nutrient recommendations to different crops

Table 5. Response of oilseeds to potassium on cultivator's fields under rainfed conditions (1980-82).

Crop	No. of trials	Response to K (kg ha^{-1}) over $N_{60}P_{40}K_0$ at		
		K_20 (3:2:1)	K_40 (3:2:2)	K_60(3:2:3)
Rabi mustard	81	89	108	142
Rabi linseed	72	48	94	142
Kharif sesamum	48	49	92	119

11. Potassium Recommendations Considering Soil Reserve K

The recommendations were at higher levels in case of black soils as compared to red and lateritic soils due to lower recovery of added K in case of black soils. Similarly, STCR based K prescription was given for 20 q ha^{-1} targeted chickpea yield on black soil of Madhya Pradesh and calcareous alluvial soils of Bihar. In black soil belt of M.P. having available K at 200kg ha^{-1}, K prescription was 61kg K_2O ha^{-1}. On other hand, in calcareous black soils of Bihar with soil test value of 50kg K_2O ha^{-1}, the K prescription was 74kg K_2O ha^{-1} to achieve 20 q ha^{-1} chickpea yields.

Categorization of soils based on potassium reserves in rainfed regions of the country: Implication in K management

Nonexchangeable K buffering characteristics along with critical levels of exchangeable K have important implications in soil K fertility management. However, nonexchangeable/reserve K is not considered in K fertilizer management. Crop fertilization with potassium in rainfed agriculture is altogether missing on the assumption that Indian soils are rich in potassium and crops do not need external K supply. However, under continuous cropping in rainfed regions, huge crop K removals are reported up to 150-200 kg ha^{-1} annually depending upon amount and distribution of rainfall and biomass production. Thus most of the crops essentially deplete soil K reserves. Soil K reserves under diverse rainfed production systems were assessed and categorized in rainfed soils based on different soil K. Depth-wise sampling was done from 21 locations across different soil types under eight production systems and various fractions of soil K were determined. Total K was the highest in Inceptisols (1.60-2.28%) followed by Aridisols (1.45-1.84%), Vertisols and Vertic sub-groups (0.24-1.72%) and Alfisols and Oxisols (0.30-1.86%) showing a wide variation within each group. Nonexchangeable K reserves were found in a proportionate manner with that of total K in most of the soil profiles. Contrary to nonexchangeable K reserves, Vertisols had higher exchangeable K than Inceptisols and Alfisols/Oxisols. Nonexchageable K showed significant positive correlation with total K in Inceptisols and Vertisols while it was non-significant in Alfisols/Oxisosls. However, significant positive correlations were recorded with exchangeable K and nonexchangeable K in all the soil types indicating the dynamic equilibrium between two soil K fractions. Nonexchangeable K reserves were also included along with exchangeable K in categorizing soils into 9 categories for evolving better strategies to manage soil K fertility in rainfed agriculture in India (Srinivasarao et al., 2007)(Table 6) Finger millet and groundnut crops at Bangalore and Anantapur regions (Category I) need immediate attention on K nutrition as these soils are low both in exchangeable and nonexchangeable K. Similarly crops grown on soils of S.K.Nagar, Ballowal-Saunkri and Rakh-Dhiansar, where exchangeable K was low and medium in nonexchangeable K, would need K fertilization as these crops are K exhaustive (maize and pearlmillet) (Category II). Pearl millet and upland rice in category III and cotton in category IV need K additions at critical stages. Upland rice in category V needs maintenance dose of K. In category VI, cereal crops may not need K additions immediately as they have medium exchangeable K and high nonexchangeable K. Long term sorghum cropping may need K supply after few years (category VII). Soils under category VIII are adequate in nonexchangeable K and medium exchangeable K and crops viz., groundnut, cotton, sorghum and soybean may not need external K immediately. While for soils under category IX, K fertilization is not required to the crops (sorghum and soybean) as these soils had high exchangeable and nonexchangeable K. As an aid to guide for ferttilizer recommendation the critical level of nonexchangeable K for different

Table 6. Categorization of soils based on soil K reserves and K recommendations for different rainfed regions in India

Category	Exchangeable K	Non-Exchangeable K	Locations	Recommendation
I	Low	Low	Bangalore (Alfisol, Karnataka), Anantapur (Alfisol, Andhra Pradesh)	Inclusion of K in fertilization is must as finger-millet based production system at Bangalore is K exhaustive and soil K status is low

Category	Exchange-able K	Non-Exchange-able K	Locations	Recommendation
II	Low	Medium	S.K.Nagar (Aridisol, Gujrat), Ballowal-Saunkri (Inceptisol,Punjab), Rakh -Dhiansar (Inceptisol, Jammu & Kashmir)	K fertilization is essential as maize and pearlmillet systems are K exhaustive and soil K levels are low.
III	Low	High	Agra (Inceptisol, Uttar Pradesh), Ranchi (Alfisol, Jharkhand), Varanasi (Inceptisol, Uttar Pradesh)	K additions at critical stages of crops improve yield levels.
IV	Medium	Low	Akola (Vertisol, Maharashtra)	Continuous cotton system needs K addition at critical stages as non exchange-able K fraction does not contribute to plant K nutrition substantially.
I	Low	Low	Bangalore (Alfisol, Karnataka), Anantapur (Alfisol, Andhra Pradesh)	Inclusion of K in fertiliza-tion is must as finger millet based production system at Bangalore is K exhaustive and soil K status is low
V	Medium	Medium	Phulbani (Alfisol, Orissa)	As soils are light textured, maintenance doses of K may be required for upland rice systems
VI	Medium	High	Hisar (Aridisol, Haryana), Arjia (Vertisol, Rajasthan), Faizabad (Inceptisol, Uttar Pradesh)	Crops may not need immediate K additions.
VII	High	Low	Bijapur (Vertisol, Karnataka)	Long term sorghum system would need K additions after few years
VIII	High	Medium	Rajkot (Vertisol, Gujrat), Kovilpatti (Vertisol, Tamil Nadu), Bellary (Vertisol, Karnataka), Solapur (Vertisol, Maharashtra), Indore(Vertisol, Madhya Pradesh)	K application is not required immediately.

IX	High	High	Jhansi (Inceptisol, Uttar Pradesh), Rewa (Vertisol, Madhya Pradesh)	K application is not required.

Exchangeable K: Low=<50 mg kg^{-1}, Medium= 50-120 mg kg^{-1}, High= >120 mg kg^{-1}

Nonexchangeable K: Low=<300 mg kg^{-1}, Medium= 300-600 mg kg^{-1}, High=>600 mg kg^{-1}

Potassium recommendations for some dryland crops

The data in the table suggests that substantial scope exists for improvement of crop productivity in rainfed agriculture with improved management (Table 7). Correction of nutrient deficiency is one the important factor in improving the productivity. Potassium application is must in some of the rainfed crops when these crops are grown on light textured red and lateritic soils, light textured acidic and problematic soils. Among rainfed crops, sunflower, cotton, maize, sorghum, rice, quality crops like horticulture and vegetables, and tobacco needs K application.

Table 7. Contribution of production inputs to yields in rainfed agriculture

Input	Practices	Average yields of crops (q/ha)	
		Sorghum	Pearl millet
Seed	Traditional	7.5 (100)	14.6 (100)
	Improved	15.7 (210)	19.7 (192)
Fertilizer	Traditional	11.0 (100)	13.0 (100)
	Improved	18.8 (171)	20.8 (160)
Management	Traditional	10.9 (100)	14.5 (100)
	Improved	16.9 (155)	19.3 (133)

Many rainfed cereals like finger millet, sorghum, maize, upland rice the K recommendation varied from 40 to 60 kg ha^{-1} depending upon soil type. Red and lateritic soils of southern and eastern India need special attention on K nutrition of crop plants. For pulse crops and soybean this ratio can be 1:2:1 and K recommendation varied between 30-40 kg ha^{-1}. Oil seed crops need K varying between 40 kg ha^{-1} (groundnut) to 60-80 kg ha^{-1} (Sunflower) depending upon soil type. For K loving crops like potato, cassava, banana potassium recommendations should be almost equal to that of N (Table 8).

Table 8. Suggestive $N:P_2O_5:K_2O$ ratios for important crops and soil types in different regions of India

Crop	Region	Soil type	$N:P_2O_5:K_2O$
Rice	Indo-Gangetic	Alluvial	5:2:1.5
	Central India	Black	5:2:1
Wheat	Indo-Gangetic	Alluvial	5:2:0.5
	Central India	Black	6:2:1
Soybean	Central India	Black	1:2:1
Pulses/Chickpea	Indo-Gangetic	Alluvial	1:2:1
	Central India	Black	1:2:0
	South and Eastern India	Red	1:2:1
Oil seeds	South and East	Red	3:2:2
	Central India	Black	3:2:1
Potato	North India	Alluvial	4:2:2
Banana	South/Central	Black/Alluvial	4:2:4
Tobacco	South India	Light	2:1:2
	Karnataka	Light	1.5:1:3
Cassava	Kerala	Acid soils	1:1:2.5
Sugarcane	North India	Alluvial	4:2:3
	Central/South India	Black	4:2:2
Tea	South India/Kerala/ Tamail Nadu	Acid soils	1:1:1.5

Organic Sources of Potassium

Organic source of K include crop residues, farmyard manure, compost, vermicompost, poultry manure, bio-gas slurry, wood ash, cow dung and cake ash etc. Part of K needs of crops can be met by recycling crop residues and adding organic manures. What is needed is a serious effort in this direction. Interest in organic manures has recently increased due to their demand for organic farming. Nevertheless these sources of plant nutrients are of great importance in field crop production. In addition to supplying plant nutrients, organic manures also improve soil physical and biological properties and thus soil health in general, which helps in making agriculture sustainable.

12. Conclusions

1. Considering the contribution of non-exchangeable-K and subsoil-K towards crop nutrition, the current soil test based on exchangeable-K content in surface (0-15 cm) soil needs to be suitably modified.

2. Red and lateritic soils spread over eastern, north-eastern and southern India, which have many dryland crops including upland rice as the dominant crop and are poor in all forms of K and total K need adequate fertilization beyond the golden ratio of 4:2:1.

3. Black soils, where sorghum, soybean, pigeonpea and groundnut are the dominant crops are rich in exchangeable and total K and potassium fertilizer recommendations should prevent mining of K from these soils. However, in shallow black soils and light textured Vertic sub group soils need K application depending upon cropping intensity and quality of crop.

4. Most of the horticultural crops (fruits and vegetables) need K application and special care should be taken when these crops are grown on red, lateritic, light textured and acidic alluvial soils. Most of banana growing regions are low in K and due to high K requirement of banana, regular K application is must.

5. High K required crops like tuber crops, quality crops like tobacco and tea, export oriented crops like flowers, spices like pepper and cardamom (growing on acid and acid sulphate soils of Kerala and coastal regions) need K fertilization.

6. Alluvial soils of north Indian rice-wheat based cropping system belt are quite rich in non-exchangeable-K and total K in surface soils as well as in subsoil, but there are pockets where K mining due to intensive cropping has been done and need K fertilization.

7. Spraying of rainfed crops with KCl solution during drought or intermitted drought will be one of the drought mitigation strategies in dryland agriculture.

8. An all-out effort needs to be made to meet part K needs of crops from organic manures and crop residues.





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